GROWTH, DEVELOPMENT AND WATER USE BY SALTCEDAR (TAMATIX PENTANDRA) UNDER DIFFERENT CONDITIONS OF WEATHER AND ACCESS TO WATER (*)

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ABSTRACT

Near Buckeye, Arizona, six evapotranspirometers were installed in 1959 and planted to saltcedar. This is a cooperative endeavor by the U.S. Bureau of Reclamation and the U.S. Geological Survey to determine the use of water by this phreatophyte.

During the spring and summer of 1961 and 1962 growth (increase in length of branches) and development (increase in number of side shoots on these branches) were observed and recorded. The data so obtained could be correlated with the measured use of water and with the accessibility to water.

Results of these studies, are the following : Saltcedar does not grow or develop in this area when the depth to water is 18 feet or more. Saltcedar tanks use more water with higher water tables but there are no significant differences in growth or development if the depth to water is 9 feet or less. Saltcedar grows and develops fast in the early spring with rapid increase in use of water; by mid-summer both growth and development level off sharply with a drastic reduction in water use, eventhough accessibility remains the same.

RESUMÉ

Près de Buckeye, Arizona, six lysimètres ont été installés en 1959 et des Tamarix (*Tamarix pentandra*) ont été plantés. Le Bureau de Réclamation et le Service Géologique des États Unis s'efforcent coopérativement de déterminer l'usage d'eau par ces phréatophytes.

Pendant le printemps et l'été de 1961 et de 1962 nous avons observé et pris note de la croissance (l'allongement des branches) et du développement (l'augmentation du nombre des brins secondaires) de ces plantes. Les données obtenues ainsi peuvent être mises en corrélation avec l'usage d'eau mesuré et avec l'accessibilité à l'eau.

Ce papier contient les résultats de ces études, comme suit : Le Tamarix ne croît pas ni ne se développe dans la région étudiée si la nappe d'eau souterraine est à plus de six mètres de profondeur. Le Tamarix utilise plus d'eau avec une nappe souterraine plus élevée, mais les différences en croissance ou en développement ne sont pas importantes si la nappe d'eau est à moins de 2,7 mètres de profondeur. Le Tamarix croît et se développe rapidement au commencement du printemps avec un usage d'eau augmentant; au milieu de l'été la croissance et le développement diminuent tout-à-coup avec une réduction rigoureuse d'usage d'eau, l'accessibilité restant la même.

INTRODUCTION

Saltcedar (Tamarix pentandra Pall.) was introduced into this country from the Mediterranean region probably by the early Spanish settlers. Although the plant found here a habitat similar to that of its lands of origin, it would in all likelihood have adjusted itself to be an unobtrusive part of the landscape. Men, however, started (as usual), to interfere with the dynamic equilibrium of nature, in this case, by building dams in rivers, thereby lowering the ground water table downstream. This lowering

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is aggravated by excessive pumping for irrigation water. Such actions prevent the natural vegetation from maintain itself. Only plants with a deeply penetrating root system can survive and saltcedar is exceptionally well equipped for such survival.

Since the beginning of the present century altcedar has spread over thousands of hectares along streams and washes. The dense vegetation causes floodwater to spread and deposit huge quantities of sediments, thus further increasing the danger of flood damage. Due to its root system saltcedar not only survives where other plants succumb, but it also continues to transpire, where other plants would have wilted long ago. It has been estimated that millions of cubic meters of water are transpired into the air, which otherwise might have remained in the ground and might have been available for pumpage.

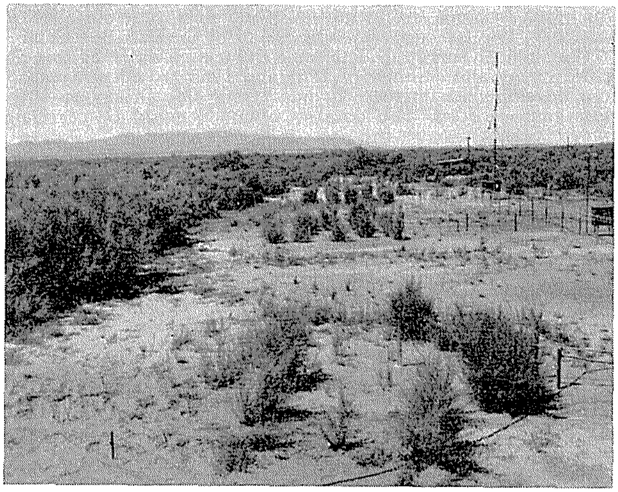


Fig. 1 — View of Buckeye Project area looking North, May 1960.

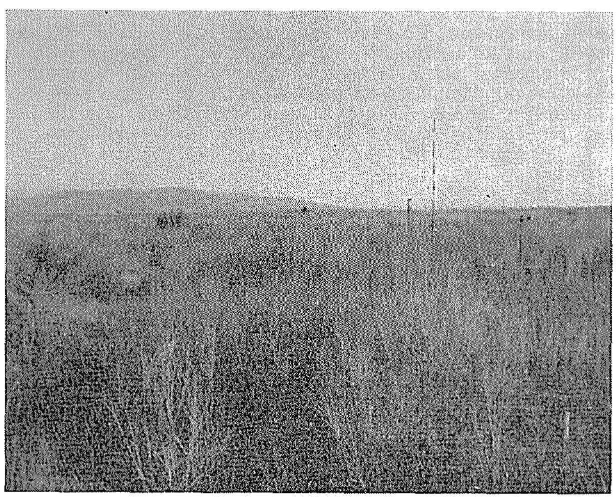


Fig. 2 — Same as fig. 1 in February 1963.

It has proven very expensive to eradicate saltcedar thickets, so it became necessary to ascertain the actual quantities of water altcedar uses in order to be able to justify the cost of eradication. Several studies on this subject have been made but with equivocal results. The Buckeye project, where large (10 × 10 meter) evapotranspirometers are used in a homogeneous coverage of dense saltcedar groves inside as well as outside the tanks, is designed to eliminate ambiguity and to deliver eventually unequivocal data on the water use by saltcedar.

The history of the project was described by Bowser and Robinson (1959), the design and methods have been delineated by van Hylckama (1960). Some data on the water use have already become available but these results are necessarily of a preliminary nature because the vegetation has not yet reached its fuli density. Figure 1 shows the area shortly after the installation of the evapotranspirometers in May 1960; figure 2 represents the situation in March 1963.

It was soon apparent that there should be available some sort of quantitative data on the development and growth of the saltcedar in case it became necessary to explain certain changes in water use inconsistant with the classical effects of radiation air temperature, wind vapor pressure and other environmental factors.

This paper described the methods used and the results derived from the analyses of the data obtained.

History

When studies are made of the use of water by plants, it is frequently assumed that, provided they are never short of water, the transpiration rate is determined by the weather conditions at the site. For this to be true at all it needs further to be assumed that the vegetation is of uniform height and forms a close stand completely shading the ground, (Penman 1955). Under such conditions the amount of water transpired per unit time is said to be the potential evapotranspiration (Thornthwaite 1948, Penman 1948).

The vegetation on the evapotranspirometers at the Buckeye project forms with the surrounding vegetation an evenly growing, homogeneous stand of saltcedar. Since the water in the tanks is near the surface the plants can draw on it freely and one might expect transpiration to take place at the potential rate, provided the assumptions are true.

The controversy on the subject of the effect of soil moisture availability on water use is still raging. There are authors who maintain that evapotranspiration continues at a potential rate, so long as the moisture content (in the root zone) is above the wilting percentage (Veihmeyer and Hendrickson 1955, Veihmeyer 1956). Others say that a decrease in soil moisture necessitates a decrease in water use (Thornthwaite and Mather 1955, Kramer 1956). An intermediate position is taken by Penman (1955) who considers that limited supplies can come from the soil below the root zone.

Penman points out, that the evidence cited one way or another is often irrelevant because it deals with growth rate, tethar than water use and growth rate may desline before there is a decline in the rate of water use. It is often assumed that for maximum growth it is necessary for the plant to maintain a maximum rate of transpiration. It does not seem that this «axiom», as Penman calls it, has ever been proven, certainly not as a general rule. But what about the opposite? Does a plant having optimum access to water ever stop growing at the maximum rate ,permitted by weather conditions? And if the plant for one reason or another — other than weather or water conditions — stops growing at the maximum or optimum rate, does that coincide with a decline in water use?

These questions have, to our knowledge, never been studied together, the emphasis always having been on either growth rate or water use.

Methods

Water use by evaporation from the tanks and by transpiration by the vegetation on the tanks is measured by a water meter. The inflow is regulated by a magnetic valve activated via a floatless electric level control system. The time and duration of inflow is registered on a recorder. See figure 3.

There is a very large daily variation in water use but weekly and monthly totals between tanks agree very well. The latter were the data used in this study. We can, therefore, neglect the daily variations at the present time, although they certainly need an eventual explanation.

It is interesting that water use increases with decreasing depth to water. This is probably more a matter of evaporation than of transpiration. It was noteworthy that during the winters 1960/61 and 1961/62 evaporation from the tanks with water tables at 1.20 or 1.50 meter continued, whereas from the tanks with a water table at 2.10 meter no water use was observed.

A record of plant growth that could easily by expressed quantitatively without cutting or otherwise damaging the vegetation was needed. Such systems have been developed. especially by the Laboratory of Climatology in Centerton, New Jersey under the leadership of C.W. Thornthwaite for example. (Higgings 1952). No such detailed phenological observations have been made on perennial vegetation, at least not on saltcedar.

The following methods were used. On a number of branches 30 side shoots were counted beginning at the top and a tag tied at the connection of the thirtieth side shoot. The length of the thirtieth side shoot was measured and the number of tertiary shoots recorded. Next the length of the lowest tertiary shoot on the thirtieth shoot was measured and again the number of shoots on that tertiary shoot counted.

These observations of counts were repaeted with weekly and sometimes shorter intervals. Also new series of observations on different bfranches, not necessarily on different shrubs, were started at weekly or biweekly intervals.

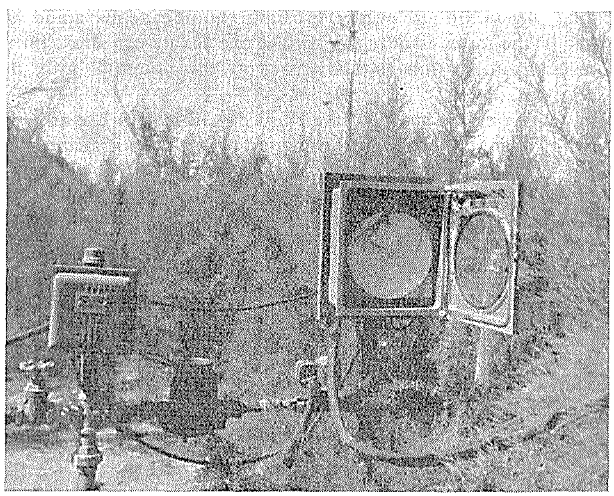


Fig. 3 — Water use recording system on evapotranspirometer at Buckeye Project. Left to right – Valve to close off flow, liquid level control box, water meter, magnetic valve and recorder. One pin records time and duration of inflow, the other the temperature of the inflowing water.

TABEL 1

Differences in growth and development of saltcedar between June 5 and July 21, 1961
Watertables : D at 6, W at 2 meters
a : growth
LENGHT OF SHOOTS (CENTIMETERS)

	1 Primary		2 Secondary		3 Tertiary	
	D	*W*	*D*	*W*	*D*	*W*
	.9	2.0	.3	.4	0	.1
	5.0	4.0	.4	1.6	.1	.3
	.8	2.4	.3	.8	.3	.3
	.3	24.5	.5	3.5	.2	.2
	2.0	44.1	.4	1.5	.3	.3
	.8	8.5	.3	3.1	.1	.4
	4.3	11.3	.4	1.0	.5	1.2
	3.8	5.3	.8	.8	.5	.5
	1.0	39.0	.2	15.5	0	.1
	1.6		1.8		.3	
Mean	2.0	15.7	.5	3.1	.2	.4
l.						
l.s.d. (*)	10.9		3.2 (n.s.)		.25 (n.s.)	

b : development
NUMBER OF NEW SIDE SHOOTS

	4 Secondary		5 Tertiary		6 Quaternary	
	2	19	2	3	0	0
	10	12	0	0	0	0
	5	17	0	1	0	0
	3	25	5	13	0	0
	10	34	1	8	0	0
	4	28	2	8	0	0
	17	17	4	7	0	2
	11	28	3	3	8	2
	1	52	2	56	0	5
	10		10		4	
Mean	7.3	25.8	2.9	11.0	1.2	1.0
l.s.d. (*)	8.8		11.8 (n.s.)		2.2 (n.s.)	

(*) Least significant difference at the 5% level using Student's *t*-test. For column 4 the l.s.d. is also significant at the 1% level (12.0).

It soon became clear that there were large variation not only at the start of a series of observations but also during further growth and development, even on shrubs that to all appearances grew under identical conditions of soil and exposure. We suspect that a saltcedar population consists of individuals with widely different inhereted characteristtics of rate of development, lengths of internodes, color of bark and flowers, and time of flowering.

As an example table 1 presents the data on one series of observations on two sets of plants, one growing in dry soil with a water table at 6 meter, the other in one of the tanks with a water table at 2 meters. Only the difference in increase in length of the primary shoot and the increase in numbers of secondary shoots on the primary one are statistically significant. The other differences are not significant, mainly because of the veery large variation with in each set of measurements.

If one wants to compare growth and development data for different years with one another, it is desirable to convert the calendar days into some type of growth units. Temperature data can be used for this purpose, for instance the accumulated degrees Fahrenheit for all days having a mean temperature above 40.

Thornthwaite (1948) improved upon this method by taking into account latitude and length of daylight. His method, although mathematically elaborate, is easy to apply with the help of tables and nomograms. Thornthwaite's "growth units" are actually units of water, in this case centimeters, used by a homogeneous vegetation fully covering the ground and having an unrestricted supply of water. The quantity of water so used is the potential evapotranspiration (P.E.) refered to previously. The method has not always been satisfactory in its application to dry climates but since we are comparing two years in the same surroundings this deficiency can be neglected.

(Penman (1948) developed a more complicated and somewhat less empirical method including the use of energy budget and mass transfer theories. The Buckeye project is equipped with instrumentation to take energy budget and mass transfer variables into account but data reduction is not complete. The Thornthwaite method, therefore, was used for simplicity.

Results

a. *Water use*

Table 2 summarizes the measurements of water used by tank pairs and by months for the years 1961 and 1962. In 1961 the shrubs (which were planted in 1959 from crown and stem cuttings) grew very fast and reached a maximum of water use in July. At that time tanks 2 and 6 with a deeper water table showed greater water use than tanks 1 and 4. Otherwise, there is a clear and distinct decline of use with increasing depth to water.

In 1962 there is again an increasing use of water from January through June. The vegetation increased in height and density, as judged by methods proposed by the Subcommittee on Phreatophytes (1958). Suddenly, however, the water use dropped by nearly 50 percent in July and steadily diminished thereafter but remained higher than in the previous year. Figure 4 shows the monthly water use through the two years for all six tanks added together. The sudden drop in water use stands out very clearly as does the fact that water use remained higher through the late fall of 1962 than in 1961.

Rainfall, (given in fig. 4), in both years was small : 95 mm in 1961 and 112 mm in 1962. The "normal" rainfall for this area is about 200 mm per year. Some effect on the use of tank-water can be observed nonetheless, Especially the low water use in February and March 1962 might be due to the previous December rains.

TABLE 2

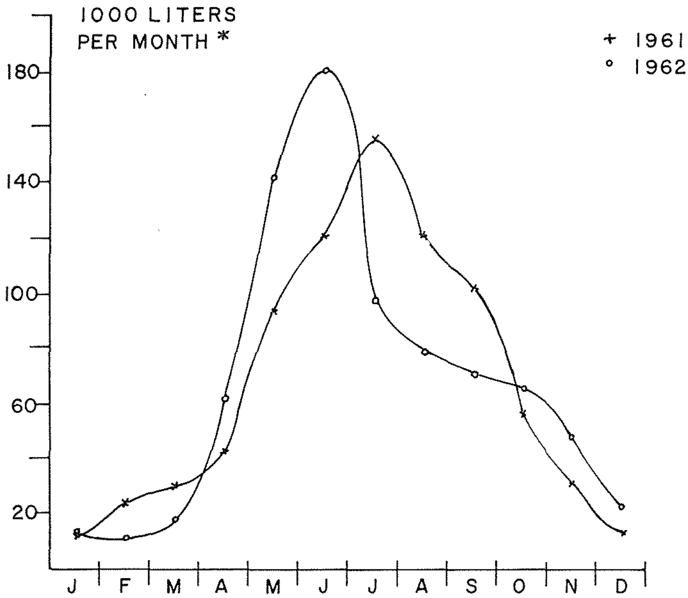
Water use by saltcedar. Means of tank pairs in 1000 ilters per month and total for all tanks

Tank	J	F	M	A	M	J	J	A	S	O	N	D	Year
3 and 5	Depth to water 1.5 meter												
1961	3.0	8.6	9.8	11.1	20.9	23.6	31.9	27.0	22.8	19.1(*a*)	11.6	5.5	194.9
1962	4.6	3.7	5.9	20.8	33.6	42.4	24.1	21.5	18.2	16.9	12.6	6.0	210.3
1 and 4	Depth to water 2.1 meter												
1961	2.3(*a*)	1.8	3.0	6.3(*a*)	12.2	20.6(*a*)	20.7	17.0	13.8	7.2	4.5	.9	110.3
1962	1.7	(*a*)	(*a*)	9.8	23.2	30.0	16.1	11.7	10.2	9.2	7.2	3.4	127.3(*a*)
2 and 6	Depth to water 2.7 meter												
1961	.9	1.6	2.5	3.9	13.4	16.4	25.4	17.0	14.9	2.5(*a*)	0	0	98.5
1962	0	0	0	0	14.3	17.7	8.7	6.7	7.0	6.9	4.8	2.2	68.3
All tanks													
1961	12.3	24.0	30.5	42.4	93.0	121.4	156.1	121.8	102.9	57.5	32.2	12.7	
1962	12.5	11.2	17.8	61.1	142.2	180.1	97.6	79.8	70.8	65.9	49.2	23.0	

Discrepencies in totals are due to rounding off to nearest 100 liters.

(*a*) Reliable tank data incomplete. Values estimated by interpolation from other tanks, adjacent months and other years.

* A water use of 1000 liters per morth equals about 12 mm per morth per tank Rainfall has not been included in the data.



RAINFALL

	J	F	M	A	M	J	J	A	S	O	N	D	
1961	11	0	5	0	0	0	19	14	2	5	0	39	mm
1962	37	0	13	0	0	5	3	2	40	0	4	8	mm

* about 2 mm per month

Fig. 4 — Total use of water in six evapotranspirometers planted to saltcedar. (Rainfall not included).

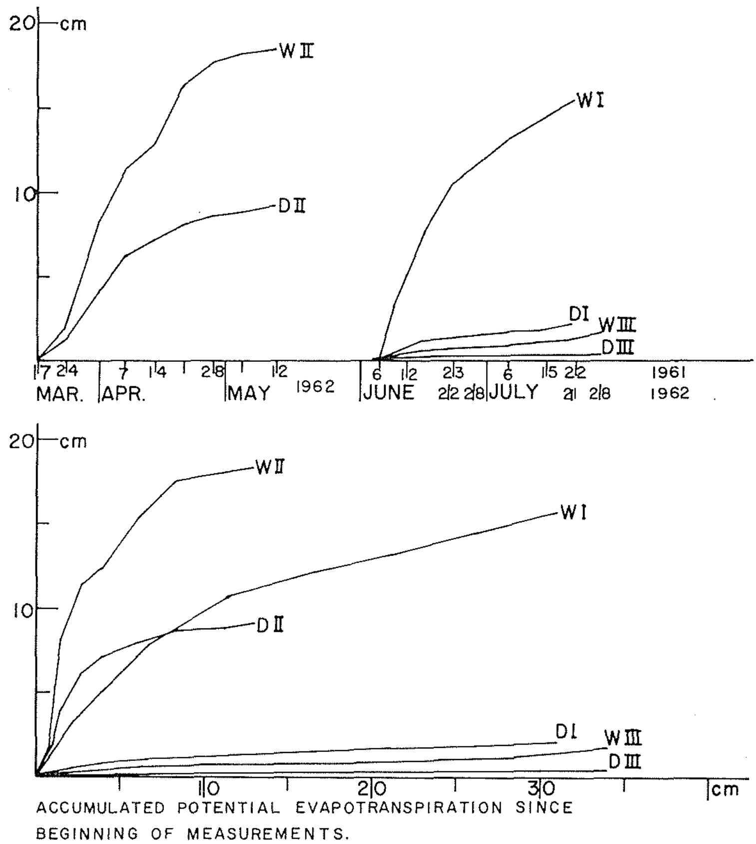
b. *Growth and development*

Of the multitude of data gathered on the growth and development only a handful is presented here. All observations, however, showed the same tendencies as the six series selected for presentation. All differences discussed in the following paragraphs were tested for significance by using the "t-test" (Fisher, 1944) and are significant at the 5 percent level, unless otherwise stated.

In figure 5 the growth of two sets of plants, in terms of increase in length of selected branches is compared as explained above. The graph at the top of the page summarizes the growth by calendar days. The graph at the bottom presents the growth of the same series but here the abscissa represents units of potential evapotranspiration, according to Thornthwaite's system (see under Methods). Of the same series the developments are graphed against calendar dates and potential evapotranspiration in figure 6.

It is quite striking that in 1961 both growth and development seem to continue at an undiminished rate through July, whereas in 1962, after a fast start in the spring both growth and development rates taper off gradually and in the summer there is hardly any difference between plants with a water table at 1.5 meter and those with a deep water table.

Several series of observations were made on the growth and development in the differents evapotranspirometers. The distinct difference in water use for the three sets of tanks gave rise to the questions whether such differences would be reflected in growth or development or both. It is still possible that such differences exist but but the data did not prove them to be statistically significant at any time.



DEPTH TO WATER	PERIOD	DAYS	TOTAL P.E.
W : 1.5 meters	I: June 5 - July 21 '61	46	31 cm
D : 5.5 meters	II: Mar. 17 - May 12 '62	56	17 cm
	III: June 2 - July 28 '62	52	42 cm

Fig. 5 — Increase in lenghts of saltcedar shoots at different times of year and with different depths to water.

Conclusions

From the data presented in the previous pages it seems quite evident that a decrease in growth and development parallels a diminishing use of water, even though this water seems to be freely available.

That earlier studies (e.g. : Gatewood et al., 1950, Makkink, 1957, Harrold and Dreibelbis, 1958, Zinke, 1959, etc.), do not show this is not surprising. They either were dealing with short term observations (one year or less), used agricultural crops, such as grasses, grains, etc., or studied yearly totals only. At this stage we can only speculate on the reasons for the decrease in rates of growth and development.

Temperature undoubtedly plays no role in the proceedings. In 1961 growth and development continued uninterrupted through the hottest part of the year when the temperature in the project area frequently exceeds 49 °C (120 °F).

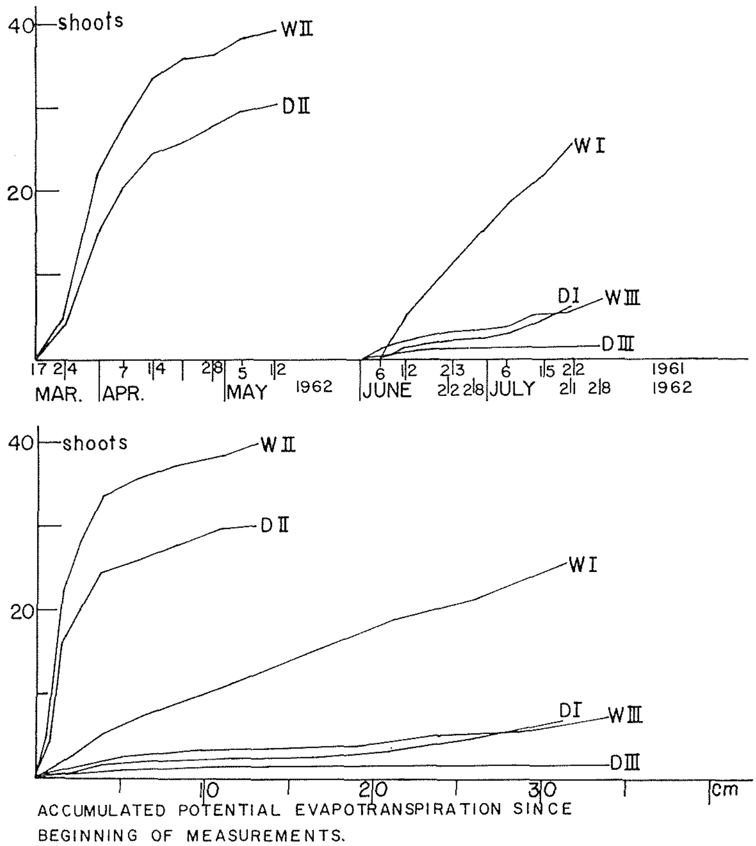


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Fig. 6 — Increase in number of secondary shoots on primary shoots of saltcedar at different times of year and with different depths to water.

The increase in plant density, which was very remarkablein the spring of 1962, may have well had one or two effects on the rate of water use. In the first place, it is conceivable that a maximum density had been reached. This means that any additional growth can take place only at the cost of decay elsewhere. It means also, however, that before this maximum was reached, the water use was larger. In other words : optimum density (for water use) is not necessarily equal to maximum density.

A second effect of increase in density may be a decrease in carbon dioxide in the air inside the thickets large enough to inhibit normal growth and development. Bonner and Galston, (1952) cite evidence that on a windless day the CO_2 content of the air in a corn field can drop from the normal .03 percent to .01. The air inside the saltcedar is indeed practically motionless on a hot summer day and aven immediatly above the vegetation, wind speeds are very low at times. We plan to record CO_2 contents during the summer of 1963 to test this hypothesis.

A third, but admittedly remote, effect may be an increase in salinity in the "ground water" in the tanks. Saltcedar is highly salt tolerant and even takes up and exudes salts. Gatewood et al. (1950) report 41,000 ppm dissolved solids in the guttation moisture. The well water at the site, which provides the "ground water" in the tanks contains 2400 ppm and the ground water itself has only 3000 ppm at the time of this writing, whereas Gatewood (l.c.) mentions that saltcedar thrives on ground water containing 8000 ppm dissolved solids.

Although there were no significant differences between growth and development of plants growing in different tanks, the differences in water use are remarkable.

Schumacher (in Fitting et al., 1951) shows that the cohesion theory explains that no extra energy is necessary for plants to draw water from greater depth, provided, it is not under stress at depth. Kramer and Kozlowski (1960), also quote evidence to the same effect. There remains then the explanation that water evaporates directly from the surface of the soil and shows at the same time that even with a water table at two meters there still is a considerable amount of water evaporating and the capillary rise apparently fast enough to follow the evaporation rate.

There is capillary rise in the tanks with a shallow water table, as is evidenced by a moist surface throughout the year and loss of water through the dormant season. One may raise the question whether such a movement of moisture would not result in a high concentration of soluble salts near the surface. This in turn could explain a decrease in growth and development and even a decrease in transpiration. Evidence of such a possibility is cited by Russell (1950). It seems most unlikely though that so early an effect of high salinity would be noticeable on *saltcedar*, the more so, since the tanks with low water table show the same diminishing rates of water use, growth and development.

The problems are far from solved and very challenging. They will be further investigated during the growing season of 1963.

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